Towards The Appreciation of Simulation

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Abstract

To know and to appreciate is an art. It is an art that requires understanding of 'what', 'do and don't', 'when and where' and 'is it' components of the subject involved. Simulation is an operations research (OR) tool used in solving problems concerning a system, by imitating the system. Thus, to appreciate this tool of OR needs the clarification regarding the components of simulation. This paper presents the answers to the question of - what is simulation, how does it work, when and where should it be applied and is it worth simulating. By collecting and understanding the answers to the question mentioned will aid in appreciating simulation as a tool to decision making and forsee the future of simulation. This paper touches on various definitions collected, the main factors of simulation, its application in specific fields and analyzing the advantages and disadvantages of simulation. It is then leave to the reader to make the conclusion regarding the significance of simulation as an OR tool towards decision making.

Abstrak

Sikap ingin tahu dan menghargai adalah satu seni. Ia adalah satu seni yang memerlukan kefahaman tentang komponen 'apakah', 'suruhan dan larangan', 'bila dan di mana' dan komponen 'adakah' bagi subjek yang terlibat. Simulasi adalah satu alat atau perkakas penyelidikan operasi yang digunakan dalam menyelesaikan masalah-masalah yang berkaitan dengan sistem iaitu dengan cara mencontohi atau meniru sistem tersebut. Jadi, untuk menghargai alat penyelidikan operasi ini, kejelasan terhadap komponen-komponen simulasi adalah diperlukan. Kertas kerja ini membentangkan jawapan kepada persoalan - apakah itu simulasi, bagaimanakah ia dilaksanakan, bila dan di mana ia patut digunakan dan adakah ia merupakan simulasi yang bermanafaat. Dengan mengumpul dan memahami jawapan-jawapan kepada persoalan-persoalan yang disebutkan itu tadi, akan dapat membantu kita menghargai simulasi sebagai satu alat membuat keputusan dan meramal masa depan simulasi. Kertas kerja ini juga menyentuh pelbagai definisi yang terkumpul, faktor-faktor utama simulasi, penggunaannya dalam bidang-bidang tertentu dan menganalisis kebaikan dan keburukan simulasi. Seterusnya, terserahlah kepada pembaca untuk membuat kesimpulan berhubung dengan peri pentingnya simulasi

sebagai alat penyelidikan operasi di dalam membuat satu-satu keputusan.

Keywords : *Operations research tool, Simulation, Computer program, Simulation model, Statistical analysis, Simulation analysis*

1. Simulation - What is it?

Simulation, initially used by operations research originated in the work of John Von Neumann and Stanislaw Ulam in the late 1940's. Refering to the Dictionary of Computer and Information Technology terms [Don B. Lynch, 1987], Simulation is defined as the representation or imitation of the performance or behaviour of the process or system by means of a model expressed in Mathematical/Graphical terms for the purposes of testing.

Schultz and Sullivan (1972) [Lehman, Richard S., 1977] define simulation as "....the modelling process by a process." Simulation is thus seen as itself a process - the operation of a model - but a process that is in some sense a copy of or parallel to a real process, the latter being the real-world process that is of interest in the theoretical context. In our example, the real process is the observed social interaction, the theory is the explanatory statement in terms of attitudes and approach and avoidence tendencies. The computer program, or some other representation , is the model; the actual operation of the model is simulation. Stated in another way, simulation is the model in operation. Refer to Figure 1.1.

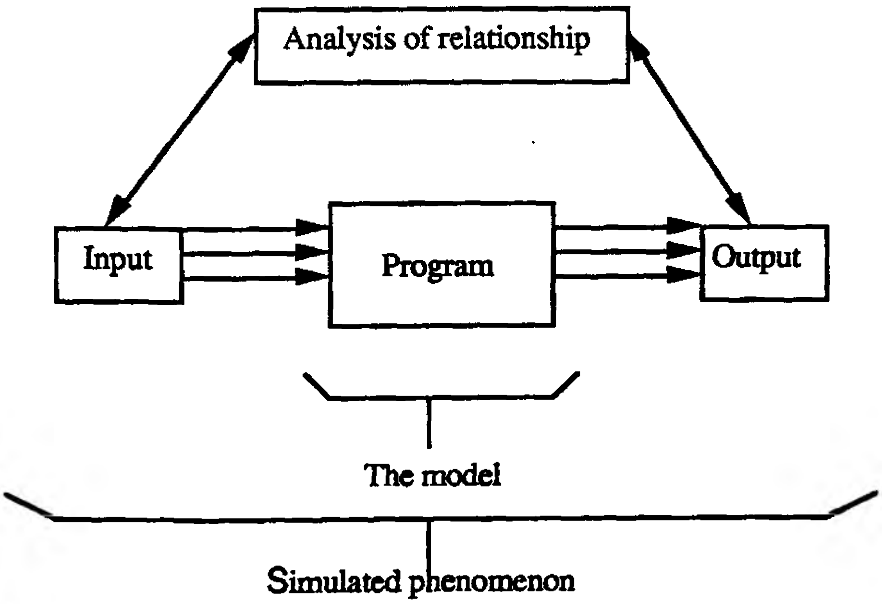


Figure 1.1

The following definition has been adopted from Naylor et al.(41) [Ravindran, Phillips, Solberg, 1987] 'Simulation is a numerical techniqeu for conducting experiments on a digital computer, which involves logical and mathematical relationship that interact to describe the behaviour and structure of a complex real-world system over extended period of time.'

From the definitions stated above, we can see that simulation is a process of creating the essence of reality without even actually attaining that reality itself. Generally speaking, a simulation model is a descriptive model of a real life system as compared to a normative model such as linear programming which generates a candidate solution. Therefore it is used to predict system performance and evaluates several strategies, algorithms,rules, etc.

Simulation can capture the necessary details of any dynamic and complex integrated system. Thus simulation is regarded as 'the next best thing to observing a real system in operation'.

2. The ABC phases of simulation

The basic phases of simulation are as following:

A. Building up of the model

B. Debugging, running and validating of the model

C. Interpretating the model output.

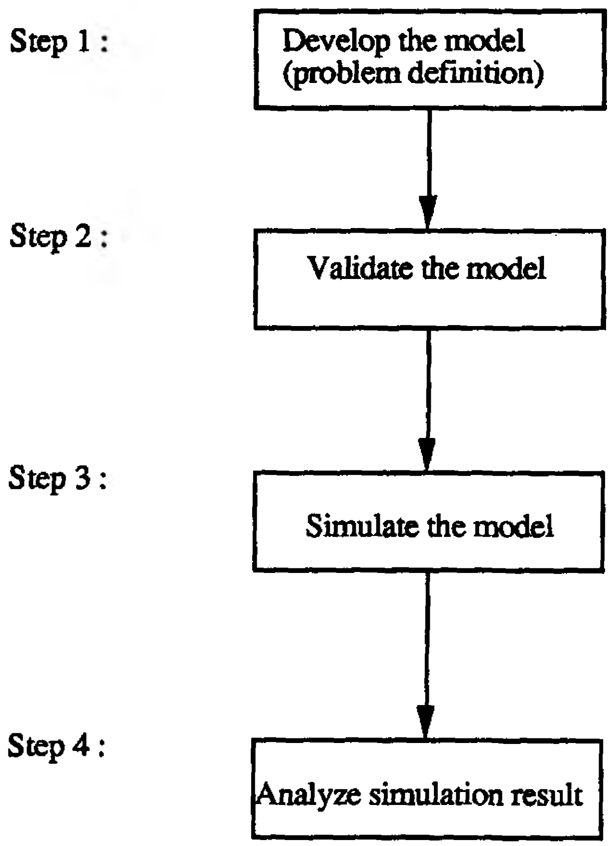
The A phase is a very time consuming and tedious work. It involves observation and collecting of correct information so as to ensure that the model constructed really represents the real system.

The B phase deals with the use of suitable simulation language to represent the logic of the model. Debugging is also essential for ensuring the logic of the model is correct. It traces the simulation computations as a function of time and checks whether the result of the model make sense. The model is then validated. One way to validate is to compare the simulation result with the result from actual past data. Once the model is validated the program is run to measure the system performance from the estimates given.

The C phase of simulation is the most crucial , to the extent if it is not done with the correct procedure and testing will result to - ' Is it worth simulating?' question. This phase is probably the most ignored by simulation users. Since simulation is a statistical experiment, the output must be interpreted statistically. Undoubtedly! the simulation experiment has perculiar statistical properties that must be observed when interpreting the results. Otherwise the output produced may be heavily biased. We must always keep in mind that failing to use proper statistical techniques may render the results of simulation worthless. Unfortunately, this aspect of simulation is often ignored because a simulation user may not always be well trained in the use of statistical techniques. This deficiency, coupled with lack of knowledge about the peculiarities of the simulation experiment, may have contributed to the misuse of simulation. The fact that some popular simulation languages have neglected this aspect in the past is also a contributing factor to the current improper interpretation of simulation output. Fortunately the more recent languages are emphasizing the statistical aspect of simulation.

3. General procedure of simulation

The general procedure for doing a simulation analysis can be described by the following flowchart.



For step 1, a model is developed that describes the key characteristics of the system being studied. In developing a model, it is important to determine the decision variables and the uncontrollable variables. It is also important to specify all the relationships between the decision variables and the uncontrollable variables. The second step is to verify or validate the simulation model. This can be accomplished by comparing the statistics obtained from other historical data of the same system. As for step 3 and 4 , some of the critical aspects are sample-size determination or how many simulations to perform and using the correct statistical techniques to analyze the results of simulation. Again, the knowledge of statistical technique plays an important role in correctly analyzing the simulation result.

Example :

In a certain factory, a tool crib is manned by a single clerk. The clerk checks out tools to mechanics, who use them to repair failed machine. (The tools involved are too expensive, and too numerous, for each mechanic to have each tool in his tool box.) The time to process a tool request depends on the type of tool. Requests fall into two categories. Pertinent data are shown in Table 1.1.

Table 1.1

Interval Times and Service Time Requirements of Mechanics Using The Tool Crib

Category of Tool Request	Mechanic Interarrival Time (seconds)	Service Time (seconds)
1	420 +- 360	300 +-90
2	360 +-240	100 +-30

The clerk has been serving the mechanics first-come, first-served, independent of request. This queue discipline is shown in Figure 1.2 where circles and triangles represent mechanics making requests in Category 1 and 2 respectively. In Figure 1.2, a Category 2 request is being served, while one request in Category 1 and two in Category 2, are waiting in that order for the server.

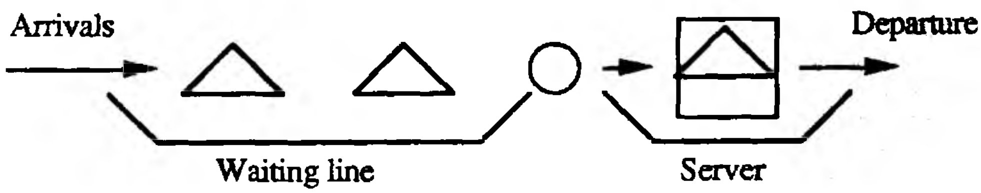


Figure 1.2

First-come, first-served queue discipline,
two customer types with priority distinctions

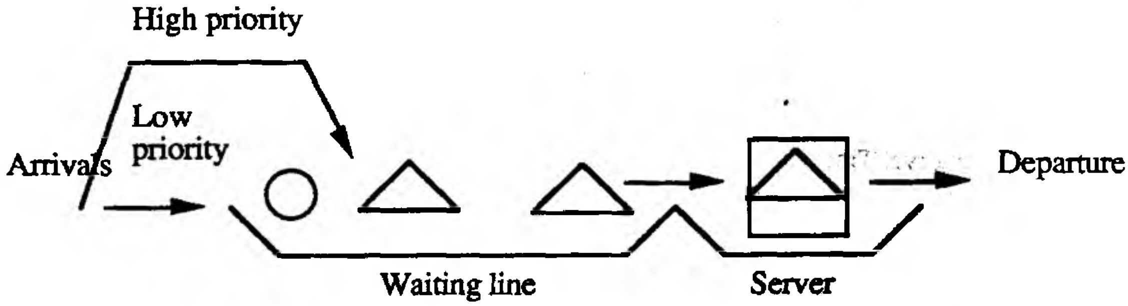


Figure 1.3

First-come, first-served queue discipline,
two customer types with priority distinctions

Because failed machines are out of production, it costs 0.25c per second ($9 per hour) when a mechanic waits for service at the tool crib. This cost is independent of the tool to be checked out. Management believes the average number of waiting mechanics can be reduced if Category 2 requests are serviced at the tool crib before those in Category 1. That is, only when no Category 2 requests are waiting is the clerk to service requests in Category 1. This queue discipline is pictured in Figure 1.3 where, in effect, the line that forms ahead of the server consists of two segments. The segment at the front of the line is of "high priority"; that at the back of the line is of "low priority." The Figure 1.3 queue discipline is said to be "first-come, first-served", within Priority Class.". The waiting - mechanic situation in Figure 1.3 is identical to that in Figure 1.2. The server is currently working on a Category 2 request (triangle). Two other Category 2 requests are waiting; and one Category 1

request is waiting (circle). Only when the high-priority segment of the line is empty will the low-priority segment be served.
(This example is taken from Simulation Using GPSS [Thomas J. Schriber, 1974])

Model Coding :

```
***********TOOL CRIB  SIMULATION...
*
*            MODEL SEGMENT 1
*
             SIMULATE
             GENERATE     420,360,,,1    CATEGORY 1
                                         MECHANIC
*                                        ARRIVE
             QUEUE        LINE           ENTER "CATEGORY     1
                                         SEGMENT" OF LINE
             SEIZE  CLERK                CAPTURE THE CLERK
             DEPART       LINE           LEAVE THE LINE
             ADVANCE      300,90  FREE THE CLERK
             RELEASE      CLERK          LEAVE THE TOOL
                                         CRIB
                                         AREA
             TERMINATE

*
*            MODEL SEGMENT 2
*            ---------------------------
             GENERATE     360,240,,,2    CATEGORY 2
                                         MECHANICS
                                         ARRIVE
             QUEUE LINE          ENTER "CATEGORY 2
                                         SEGMENT" OF LINE
             SEIZE  CLERK                CAPTURE THE CLERK
             DEPART       LINE           LEAVE THE LINE
             ADVANCE      100,30  FREE THE CLERK
             RELEASE      CLERK          LEAVE THE TOOL CRIB
                                         AREA
             TERMINATE
*
*            MODEL SEGMENT 3
*            --------------------------
             GEBERATE     28800          TIMER ARRIVES AFTER 8
                                  HOURS
             TERMINATE    1              SHUT OFF THE RUN
*
*            CONTROL CARDS
*            ------------------------
             START        1                   START THE RUN
             END                         RETURN THE CONTROL
                                         TO OPERATING SYSTEM
```

Program Output :

Figure 1.4

FACILITY AVERAGE NUMBER AVERAGE SEIZING
PREEMPTING
UTILIZATION ENTRIES TIME/TRAN TRANS.NO.
TRANS.NO

CLERK .932 140 191.874 6

QUEUE MAXIMUM AVERAGE TOTAL ZERO PERCENT
AVERAGE
CONTENTS CONTENTS ENTRIES ENTRIES ZEROS
TIME/TRANS
LINE 3 .770 140 20 14.2
158.500

cont....

$AVERAGE TABLE CURRENT
TIME/TRANS NUMBER CONTENTS
184.916

$AVERAGE TIME/TRANS =AVERAGE TIME TRANS EXCLUDING
ZERO ENTRIES

(a)

FACILITY AVERAGE NUMBER AVERAGE SEIZING
PREEMPTING
UTILIZATION ENTRIES TIME/TRAN TRANS.NO.
TRANS.NO

CLERK .959 142 194.605 1

QUEUE MAXIMUM AVERAGE TOTAL ZERO PERCENT
AVERAGE
CONTENTS CONTENTS ENTRIES ENTRIES ZEROS
TIME/TRANS

LINE	7	2.731	145	13	8.9
542.593					

cont....

$AVERAGE	TABLE	CURRENT
TIME/TRANS	NUMBER	CONTENTS
596.030		

$AVERAGE TIME/TRANS =AVERAGE TIME TRANS EXCLUDING ZERO ENTRIES

(b)

Output Interpretation :

As indicated, the Queue statistics of primary interest is the AVERAGE CONTENTS. Figure 1.4 (b) shows us that the average number of waiting mechanics when no priority distinctions are made is 2.731 for the 8 hours day simulated. When priority distinctions are made, this average decreases to 0.770, as shown in Figure 1.4 (a). Making a priority distinction, then, has led to improved system performance in the sense that the average number of waiting mechanics has been decreased by about 70%. Note that this difference is based on about 140 to 145 entries to the Queue (TOTAL ENTRIES, Figure 1.4 (a)). Due to randomness, there were five more arrivals at the tool crib during the no-priority-distinction simulation than during the priority-distinction run. When no priority distinctions are made, the cost of waiting mechanics for the day simulated amounts to about $197 (2.731 x $72/day = $196.63). With priority distinctions in effect, the experienced cost was about $55 ($55.44). The difference in the experienced cost is then about $141 ($141.19).

Despite the difference in experienced costs, the duration of simulation used in this example is so small that any conclusions drawn from the model output are tentative at best.

4. The only game in town

Simulation should only be used as a last resort when other techniques, such as linear programming, queueing theory, decision theory and etc have failed. This is due to the fact that building a simulation model for a complex system can be extremely costly in man-hours and computer time. Furthermore it does notguarantee an exact solution to the problem like one expects from analytical or mathematical programming techniques. On the other hand it may be the only technique available to solve certain problems, especially when there are too many relevant factors and too many relevant interrelations to consider for analytical or mathematical technique.

Being the only game in town, then it wise to list several ways of misusing simulation so that we will be forwarned of the do and don't of this tool.

1. Every simulation will simulate something, but not necessarily what you have intended;

2. Many people, especially those who are either ignorant of computers or desperate for a solution tend to treat computer outputs as a revelation of the absolute truth;

3. Simulation languages have succeeded in making it easier to build impressive simulation models but do not necessarily valid ones.

Do not have the impression that this paper is against simulation but it is important to realise these facts to avoid the pitfalls.

Reasons - simulation might be appropriate

The following suggestions are collected from Naylor 's (57) [Thomas J. Schriber, 1974] as an aid to decide when and where simulation might be appropriate.

1. Simulation makes it possible to study and experiment with the complex internal interactions of a given system whether it be a firm, an industry, an economy or some subsystem of one of them.

2. Simulation can be used as a pedagogical device for teaching both students and practitioner basic skills in theoretical analysis and decision making.

3. Simulation can serve as a preservice test to try out new policies and decision rules for operating a system, before running the risk of experimenting on the real system.

4. Simulation enables one to study dynamic systems in either real time, compressed time or expanded time. When new elements are introduced into a system simulation , simulation can be used to anticipate bottlenecks and other problems that may arise in the behavior of the system.

5. Simulation - Application scope

Applications of simulation analysis historically has been found in the production sector, but increasingly, better and useful models are being developed for the government and private sectors. Simulation can handle both theoretical and practical problem. First, we present the wide scope of the application of simulation in several prominent functional areas of the firm.

Physical Distribution Simulation - Simulation has enable the firm to operate a physical distribution program at the lowest possible cost consistent with satisfactory customer service. Simulation of a physical distribution system takes into account answers to the following questions:

How many warehouse should the firm use?
What are their locations and sizes?
Which market should the warehouse serve?
Should an additional plant be constructed?
What customer service level are desirable and at what cost?

Simulation has been successfully applied to a firm's physical distribution system.

Inventory - Simulation has been used regularly to inventory systems under uncertainty.For example in the effort to determine usage during lead time, computer program needs to read many random numbers as they are days in the lead time period to simulate demand during lead time. This is due to the fact that we need an adequate sample to simulate lead time. The output from the computer run would be a probability distribution and a cumulative probability of demand during lead time. This output serves as input for calculating annual stockout costs and inventory costs for each level of safety stock. Finally, the computer calculates an optimum level of safety stock for all inventory items.

Accounting - Simulation has been greatly used in accounting, especially in the field of budgeting. First and foremost, the existing budgeting system will have to be examined and translated into mathematical terms for each sub-budget. The objective is to improve the present budgeting system. The model will consists of many simultaneous equations that reflect variables, parameters and the model structure. Then the budget model is translated to computer machine language. The results of computation by the computer should yield the budgeting data of the firm simulated under certain selected conditions. The output can be arranged to print a sales budget, a manufacturing budget, a cash budget and etc. It also includes the projected income statement.

Other functional area of the firm where simulation has been put on great use are manufacturing, marketing and finance. Numerous applications of simulation can also be found in industry and the military. Simulation studies have included steel making operations to evaluate changes in operating practices, capacity and configuration of the facilities. Simulation has been used by airlines to test changes in company policies and practices. Gaming has traditionally been important to military strategist. It is a unique area of simulation which was used long before the availability of computers. In its current form, gaming permits the creation of an artificial environment that imitate a real one. Within this environment, participant engage in a competitive activity such as a military conflict. Some of the most complex simulations ever undertaken are of a war game or war scenario nature.

Despite its lack of mathematical sophistication, simulation is one of the most widely used quantitative techniques. Many researchers have demonstrated the application of simulation in increasing the efficiency of health centers.

Eyitayo Lambo [Eyitato Lambo, 1983] from University of Ibadan, Nigeria, has increased the efficiency of the health centers in his country using optimization and simulation models. Using both models, he was able to determine that faulty operational policies are more crucial factors than inadequate resources that cause the ineffectiveness and inefficiency of health institutions in Nigeria.

G. Vassilacopoulos [G. Vassilacopoulus, 1984] from the University of London uses a general Simulation Model to determine the bed complement in hospital inpatient departments to meet a predetermined demand for service. Certain constraints were considered:

(1) Emergency patients should be admitted without delay
(2) Occupancy should not fall below a certain level
(3) Waiting list length is finite - should not exceed a predetermined number

Another Simulation Model was developed by M. Barry Dumas [Barry Dumas, 1984] to address the problem of allocating beds to hospital services, by bed type and sex. The model was designed to allow experimentation with and evaluation of bed usage policies and admission rules as well as allocation plans.

Kudzdrall, Kwak and Schmitz [Kudzrall, Kwak and Schmitz, 1984] showed that simulation provides a useful tool for capacity planning and facilities management in the hospital environment where experimentation is usually impractical. Two strategies for admitting patients were simulated; one allowed random input, while the other gave priority to patients requiring longest surgery. The results of the GPSS model showed the importance of schedulling policy as the priority technique allowed 25% reduction in the surgical workday, thus providing a large savings in manpower costs

Table 1.2

Topic	Value
Probability theory	0.182
Economic Analysis	0.152
Simulation	0.143
Linear programming	0.120
Inventory	0.097
Queueing	0.085
Network Analysis	0.072
Replacement analysis	0.042
Game theory	0.040
Dynamic Programming	0.031
Search Technique	0.020
Nonlinear Programming	0.018
	1.000

The wide scope of the applications of simulation makes it one of the prominent and popular tool of OR among users. Table 1.2 shows the result of a survey conducted among a sample of nonacademic, full members of the Operations Research Society of America by Shannon and Biles [Shannon, R.E, and W.E. Biles, 1970]· The six utmost techniques used by practitioners are Probability theory, Economic Analysis, Simulation, Linear programming, Inventory and Queueing Models.

6. Conclusion

From the above information, there is no doubt that simulation has a significant place in theory and practice of operations research. It is an important tool for use on those problems where analytical techniques are inadequate. Regardless of the position which one wishes to take regarding the scope, purpose and applicability of operations research, one thing is clear - simulation can now plays a central role in the study and solution of complex problems and it is a tool with which every system analyst should be familiar. The question now is whether is it an acceptable and promising technique in the eyes of the researchers? The continual upgrading of simulation programming languages will extend their acceptance and application. Simulation has a bright future and it is highly up to the operation research believers to make the dream come true.

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